Supporting Information for "The origin of water-vapor rings in tropical oceanic cold pools"

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Text S1. To support the newly discovered role of the surface latent-heat flux in forming vapor rings, we need to address the question whether a constant bulk transfer coefficient of $C_e = 1.5 \cdot 10^{-3}$ is appropriate within cold pools. Observations presented by *Kondo*

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[1975] and *Young et al.* [1995] reveal that this value is indeed appropriate for both inside and outside of cold pools at a 10-meter level. We nevertheless tested our fluxes against those obtained from Monin-Obukhov (MO) theory which accounts for stability effects.

We carried out three further experiments. All three are initialized by a snapshot taken from R1 at $t_i = 1040$ s such that we can test the influence of different latent-heat fluxes for the same cold pool. In two of these experiments the bulk transfer coefficients for moisture are modified to $C_e = 0.75 \cdot 10^{-3}$ and $C_e = 3.0 \cdot 10^{-3}$, respectively. The third experiment applies MO similarity theory [*Dyer and Hicks*, 1970; *Stull*, 1988]) to compute the surface latent-heat flux.

Figure S2a shows that the fluxes obtained from MO theory are larger than those for constant $C_e = 1.5 \cdot 10^{-3}$. The surface layer becomes more unstable as relatively cold air moves over the warm sea surface which enhances the turbulent fluxes. The fact that we used a coefficient observed at a 10-meter height for a simulation with the lowest model level at a 5-meter height contributes to this increase. As a result, after 98 min the moisture perturbation q'_{lh} is even larger if MO theory is applied (see Fig. S2b). The other two experiments for which the constant C_e is either doubled or halved confirm the expected increase or decrease, respectively, of the fluxes and q'_{lh}.

Text S2. To further test the robustness of our findings we also studied the sensitivity to domain size and to the relative humidity in the free troposphere. Simulation R1_40 is identical to R1 but uses a larger domain of 40×40 km^2 instead of 20×20 km^2. Two further experiments, MOIST1 and MOIST2, have been carried out on this larger domain. In these simulations the relative humidity in the free troposphere is increased as

$$\mathrm{RH}(z) = (1 - \chi(z)) + \chi(z)\mathrm{RH}_{\mathrm{R1}}(z) \tag{1}$$

with $\mathrm{RH}_{\mathrm{R1}}(z)$ the relative humidity in R1 and $\chi(z)$ defined by

$$\chi(z) = 1/2\left\{(\chi_0 + 1) - (1 - \chi_0)\tanh\left[0.02(z - 500)\right]\right\}. \tag{2}$$

This yields a reduction of $1 - \mathrm{RH}$ above cloud base if $\chi_0 < 1$ and leaves relative humidities below cloud base unchanged (see Fig. S3). We set $\chi_0 = 0.6$ and 0.3 in MOIST1 and MOIST2, respectively. Compared to R1 (or R1_40), these simulations result in heavier convective precipitation, more total evaporation of rain, and thus more intense cold pools.

The evolution of the resulting moisture partitioning is shown in Fig. S4. The results from R1_40 (Fig. S4a) are basically indifferent to R1 (Fig. 3 in the letter). This is not a surprise since the simulated cloud and the emerging cold pool are basically unaffected by the increase in domain size. The cold pool clearly spreads more rapidly in MOIST1 and MOIST2. However, the partitioning remains largely unaffected and very similar to R1. Same as in R1, the pre-rain anomaly is initially considerable but decreases over time. The surface latent-heat flux contribution dominates during the entire life time of the cold pool.

References

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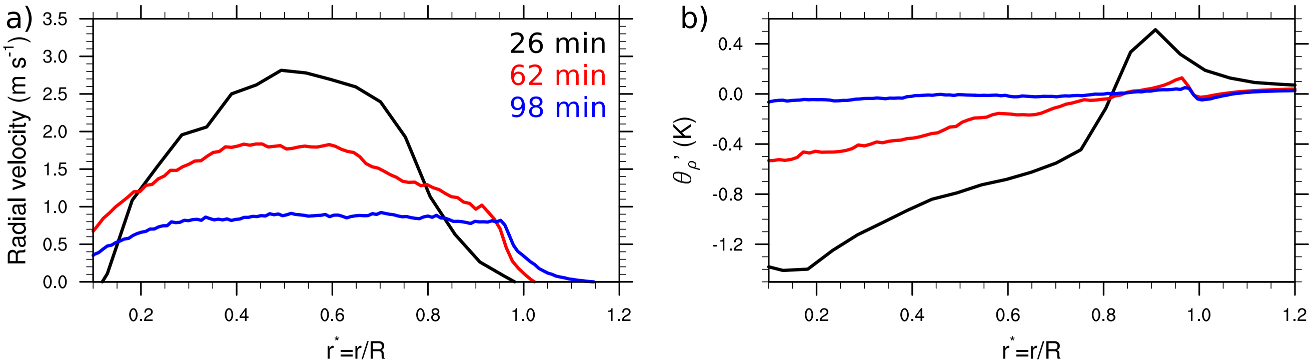

Figure S1. Illustration of the evolution of cold-pool properties as simulated in R1 at a 15-m level: (a) Radial velocity (m s^{-1}); (b) Density potential temperature perturbation θ'_ρ (K). Both quantities are shown after 16, 62, and 98 min and have been averaged in r^*-space. The leading edge of the cold pool is located at $r^* = 1$. The method used to identify the leading edge of the cold pool is decribed in section 3.1 of the paper. θ_ρ is defined as in *Emanuel* [1994] (see p. 161).

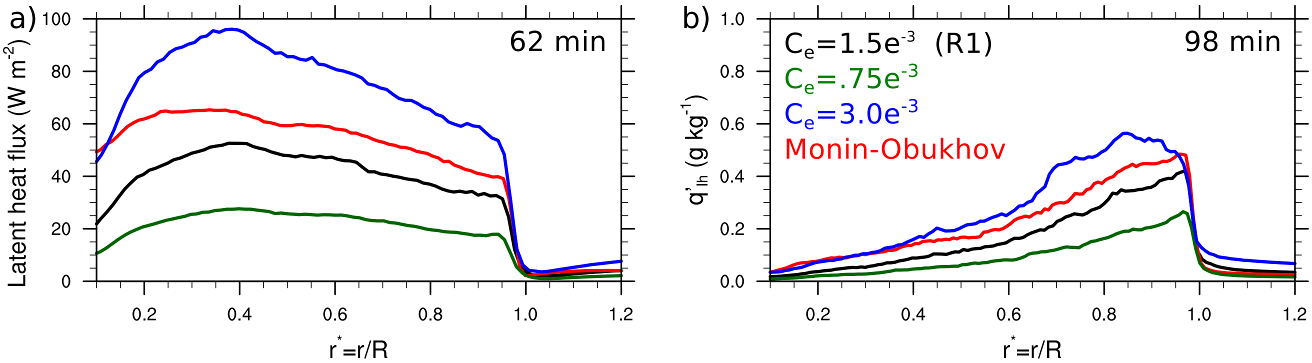

Figure S2. The sensitivity to surface latent-heat fluxes is depicted: (a) Surface latent-heat fluxes after $t = 62$ min as obtained from R1 and the three sensitivity experiments with modified transfer coefficients C_e (see text S1 for a description of experiments); (b) density-weighted vapor-mass fraction $q'_{\rm lh}$ in the lowest 100 meters after 98 min and averaged in r^*-space. MO theory yields larger fluxes as obtained for $C_e = 1.5 \cdot 10^{-3}$ and – as a consequence – an increased moisture perturbation toward the leading edge of the cold pool.

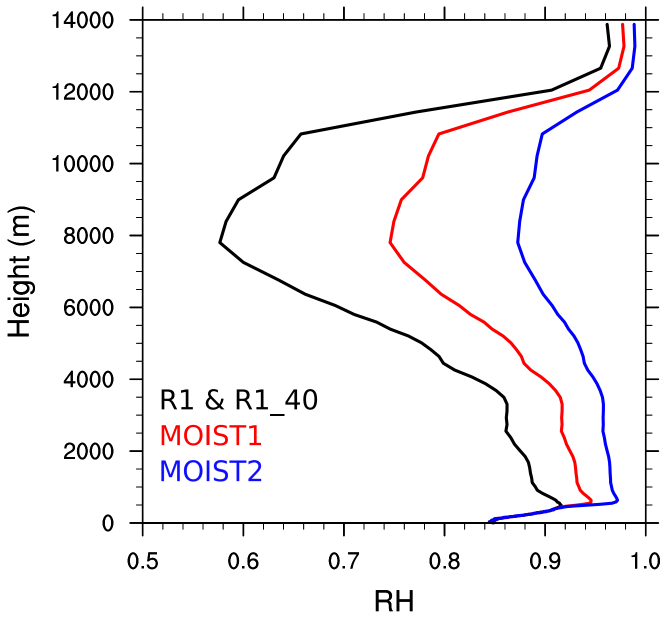

Figure S3. Initial relative humidity profiles in simulations R1, MOIST1, and MOIST2.

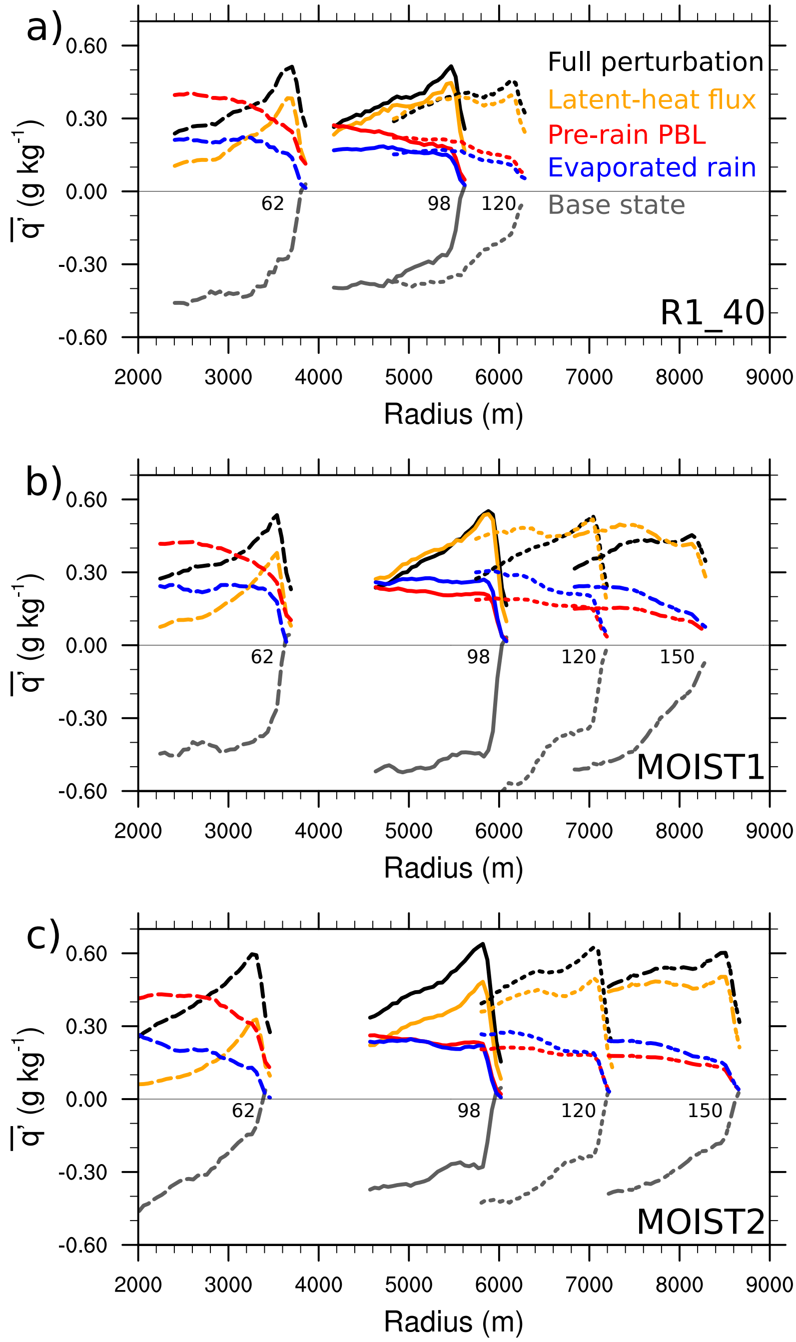

Figure S4. Same as Fig. 3 in the letter but for sensitivity experiments (a) R1_40, (b) MOIST1, and (c) MOIST2. R1_40 is identical to R1 but uses a larger 40 $\times$ 40 km^2 domain. The MOIST simulations have higher relative humidities than R1_40 above cloud base but are otherwise identical (see text S2 and Fig. S3). Cold pools in MOIST1 and MOIST2 are more intense and longer-lived than in R1_40 and we therefore added results after 150 min.